NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

August 1941 as
Memorandum Report

WIND-TUNNEL TESTS OF TWO HAMILTON STANDARD PROPELLERS EMBODYING CLARK Y AND NACA 16-SERIES BLADE SECTIONS

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NACA

WASHINGTON

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MEMORANDUM REPORT

for

Bureau of Aeronautics, Navy Department

WIND-TUNNEL TESTS OF TWO HAMILTON STANDARD PROPELLERS EMBODYING CLARK Y AND NACA 16-SERIES BLADE SECTIONS

By W. H. GRAY

SUMMARY

Tests of two 10-foot Hamilton Standard propellers were made in the propeller-research tunnel for the Bureau of Aeronautics, Navy Department, to determine the relative merits of the Clark Y and NACA 16-series sections and to determine the negative thrust available at negative angles. The propellers were identical as to diameter, activity factor, thickness ratio and pitch distribution. Tests covered a range of blade angles from -25° to 65°, and were all made at tip speeds below 280 feet per second.

The results indicated comparatively little difference between propellers at peak efficiency for the low Mach numbers experienced in the tunnel tests. The NACA 16-series sections displayed earlier stalling characteristics than the Clark Y section.

INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, the tests reported herein were undertaken at the 20-foot propeller-research tunnel, primarily to compare the NACA 16-series blade section with the Clark Y section. The Bureau of Aeronautics was also interested in obtaining data in the negative thrust range applicable to computations of maneuvers of flying boats on water.

This report gives the thrust and torque characteristics of the propellers through a range of blade angle settings from 65° to -25° at 0.75 radius, and, for the negative angles, through the complete V/nD range from $V = 0$ to nearly $n = 0$.

These tunnel tests have been confined to low tip speeds. A separate report covers compressibility measurements made on the static whirl rig at high tip speeds.

APPARATUS AND METHODS

Propellers.- Both propellers were approximately an inch greater in diameter than ten feet and have the blade-form characteristics shown in figure 1 and the plan-form of figure 3.

Propeller 6259A-18 has an NACA 16-series blade section throughout (figure 2), based on data from reference 1. Blade sections from the 36 inch radius to the tip were laid out to a larger width and then cut off at the trailing edge with a radius of .015 inch.

Propeller 6267A-18 has a true Clark Y section throughout.

Both propellers were tested in conjunction with a 28-inch diameter spinner on the streamline nacelle shown in figure 5.

Driving mechanism.- The propellers were driven by two 25-horsepower electric motors arranged in tandem. (See figure 6.) The set-up was originally designed for tests of propellers in dual rotation and for that reason the front motor was directly connected to the front propeller, while the rear motor drove the rear propeller through chains and a countershaft. For these tests the propeller shafts were locked together.

__Measurements.__- The net thrust or drag of the propeller-body combination was measured on a thrust balance located on the floor of the test chamber.

The torque of each motor was measured with a spring-Selsyn dynamometer. The motors rested on bearings concentric with the shaft axis, and were restrained from rotating by springs attached to the fixed frame. The amount of deflection of the motor frames was measured by Selsyn generator units and transmitted to indicating units on the floor.

Measurement of rotational speed was made with a condenser tachometer developed by the NACA. Frequent checks on the accuracy of the instrument were made by means of a tuning fork and oscillograph.

The tunnel speed ranged from 0 to about 110 miles per hour, and the maximum propeller speed was not over 520 rpm, or about 287 feet per second rotational tip speed.

RESULTS AND DISCUSSION

The measured values have been reduced to the usual coefficients of thrust, power, and propulsive efficiency,

$$C_T = \frac{\text{effective thrust}}{\rho n^2 D^4}$$

$$C_P = \frac{\text{engine power}}{\rho n^3 D^5}$$

$$\eta = \frac{C_T}{C_P} \cdot \frac{V}{nD}$$

for presenting the results of tests at positive angles. The effective thrust is the measured thrust of the propeller-body combination plus the drag of the body alone. "D" is the propeller diameter in feet, and "n" is the propeller rotational speed in revolutions per second.

In the negative thrust range at values of V/nD less than unity, the coefficients used have been C_T and C_Q where

$$C_Q = \frac{Q}{\rho n^2 D^5}$$

and above V/nD of unity, T_c and Q_c have been used plotted against nD/V, where

$$T_c = \frac{\text{effective thrust}}{\rho V^2 D^2}$$

and

$$Q_c = \frac{Q}{\rho V^2 D^3}$$

For the torque coefficients C_Q and Q_c, the aerodynamic torque, Q, is considered positive when the air reaction upon the propeller tends to resist rotation.

One form of the coefficients may be changed to the other by multiplying or dividing by $(V/nD)^2$.

LIST OF FIGURES

The results are given in the following figures:

The characteristic curves (see fig. 17) have been adjusted to the equivalent angle of the Clark Y blades, for three representative angles. This is necessitated by the difference in the effective blade angles based on the assumed chord lines. The figure is a comparison between the NACA 16 and Clark Y propellers, and indicates a higher thrust, power, and consequently efficiency, in the range of take-off ($0.3\ (V/nD)_{max.\ eff.}$) for the Clark Y. The same figure shows well the delayed stalling characteristic of the Clark Y as compared with the early stall of the NACA 16.

Comparison of efficiency envelope curves (see figure 18) shows very little choice between propellers. The data indicates that from one to two percent higher efficiency was realized for the NACA 16 propeller at values of V/nD below 1.6. Above this value of V/nD the Clark Y propeller varied from about the same to a little more than 1 percent higher. The crossover of the envelope could be accounted for by the fact that at the higher values of V/nD the NACA 16 profile was operating outside the range of lift coefficients for which it was designed. This is even more apparent in figures 19 and 20, which show comparisons at constant power.

Low-speed comparisons of thrust in the range of take-off and climb are shown in figure 21.

Thrust ratio comparisons at constant power in the negative thrust range show very little difference between the two sections.

CONCLUDING REMARKS

These tests, which were made in a low speed tunnel, indicated little difference in the maximum efficiency for the two propellers. Obviously, the delayed compressibility characteristics of the NACA 16-series sections would not be expected to be made evident by these tests, although they seem to check the results reported in reference 2.

The propeller with the NACA 16-series section indicated inferior take-off characteristics which, however, might be overcome by the use of larger blade areas, operation at higher tip speeds, or the use of sections designed for higher values of C_L. The possible detrimental effects of these alterations may be offset by the lower drag qualities of the section at high speeds.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 20, 1941.

REFERENCES

1. Stack, John: Tests of Airfoils Designed to Delay the Compressibility Burble. NACA TN No. 976, Dec. 1944. (Reprint of ACR, June 1939.)

2. Corson, Blake W., Jr., and Mastrocola, Nicholas: Static Characteristics of Hamilton Standard Propellers Having Clark Y and NACA 16-Series Blade Sections. NACA MR, Aug. 28, 1941.

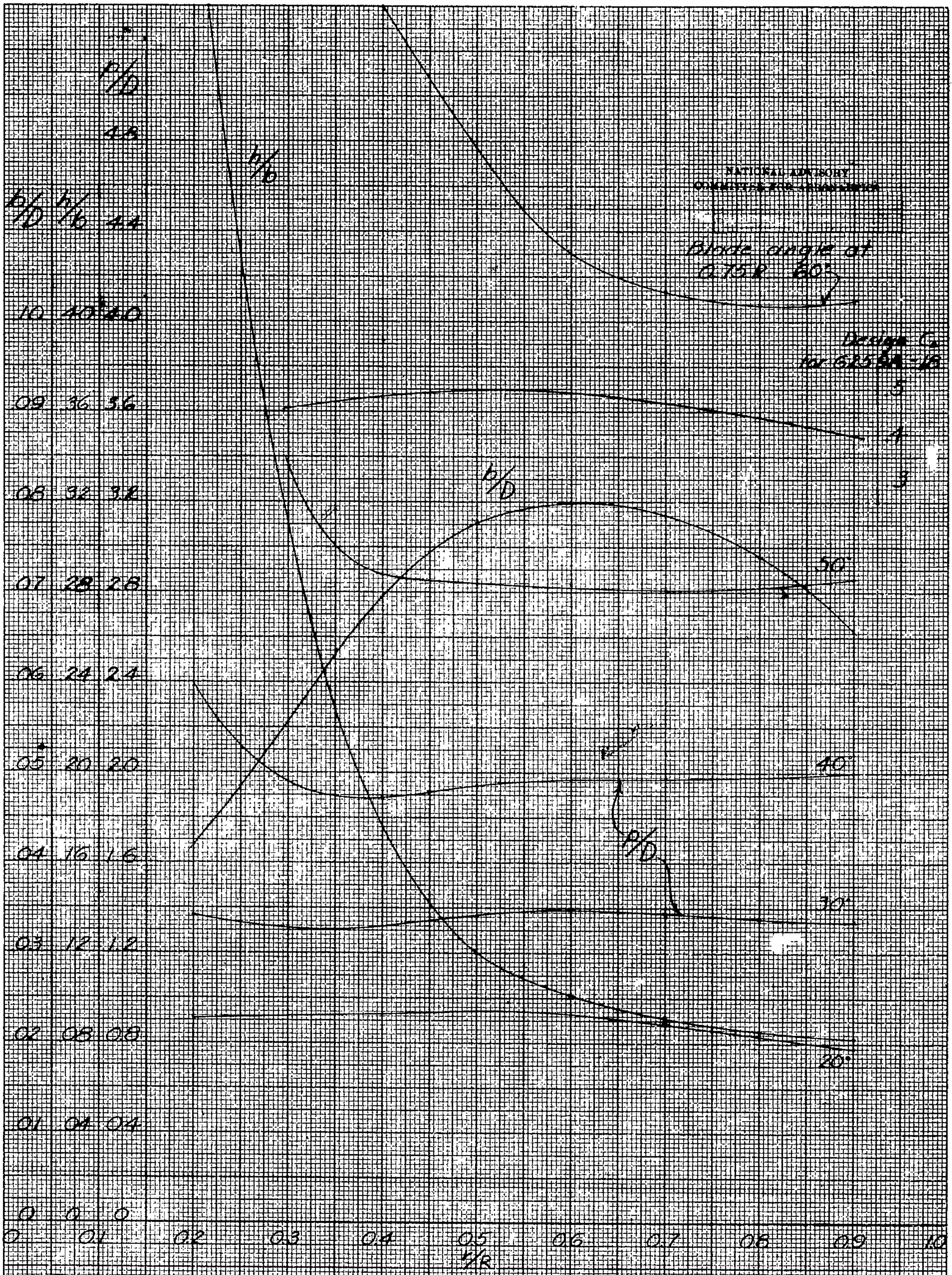
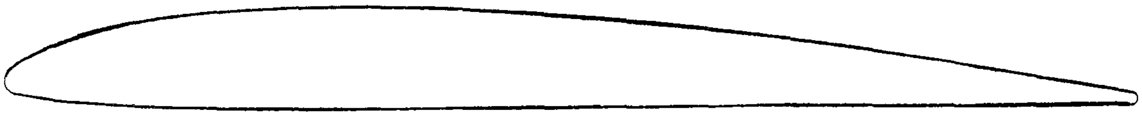


Figure 1 Blade form curves for Hamilton Standard propellers 6259A-18 & 6267A-18. D, diameter; R, radius to tip; r, station radius; b, section chord; h, section thickness; p, geometric pitch.

No. 6259A-18, NACA 16-series



No. 6267A-18, Clark-Y

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Figure 2 - Propeller blade sections at the 0.70 R.

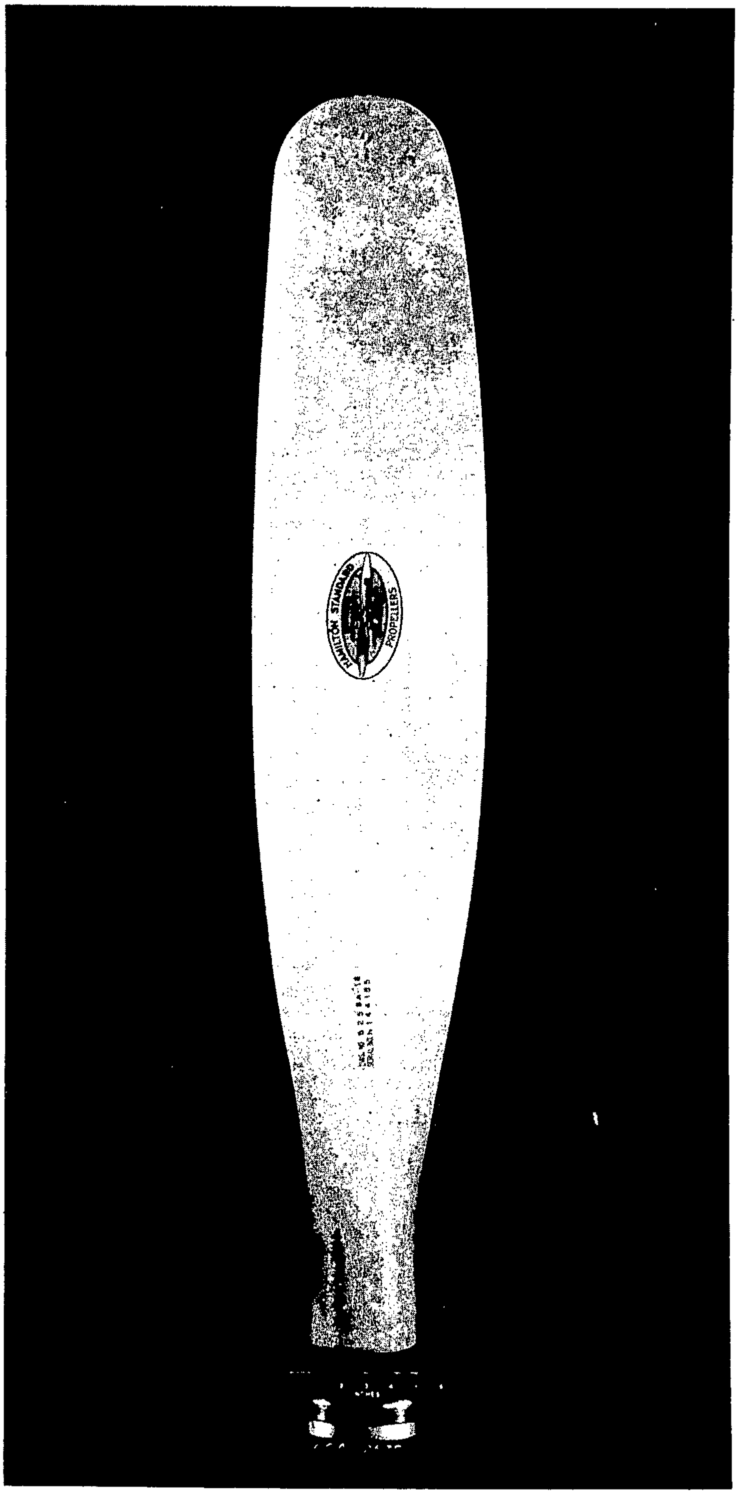


Figure 3.- Photograph showing plan form of the propeller blades tested.

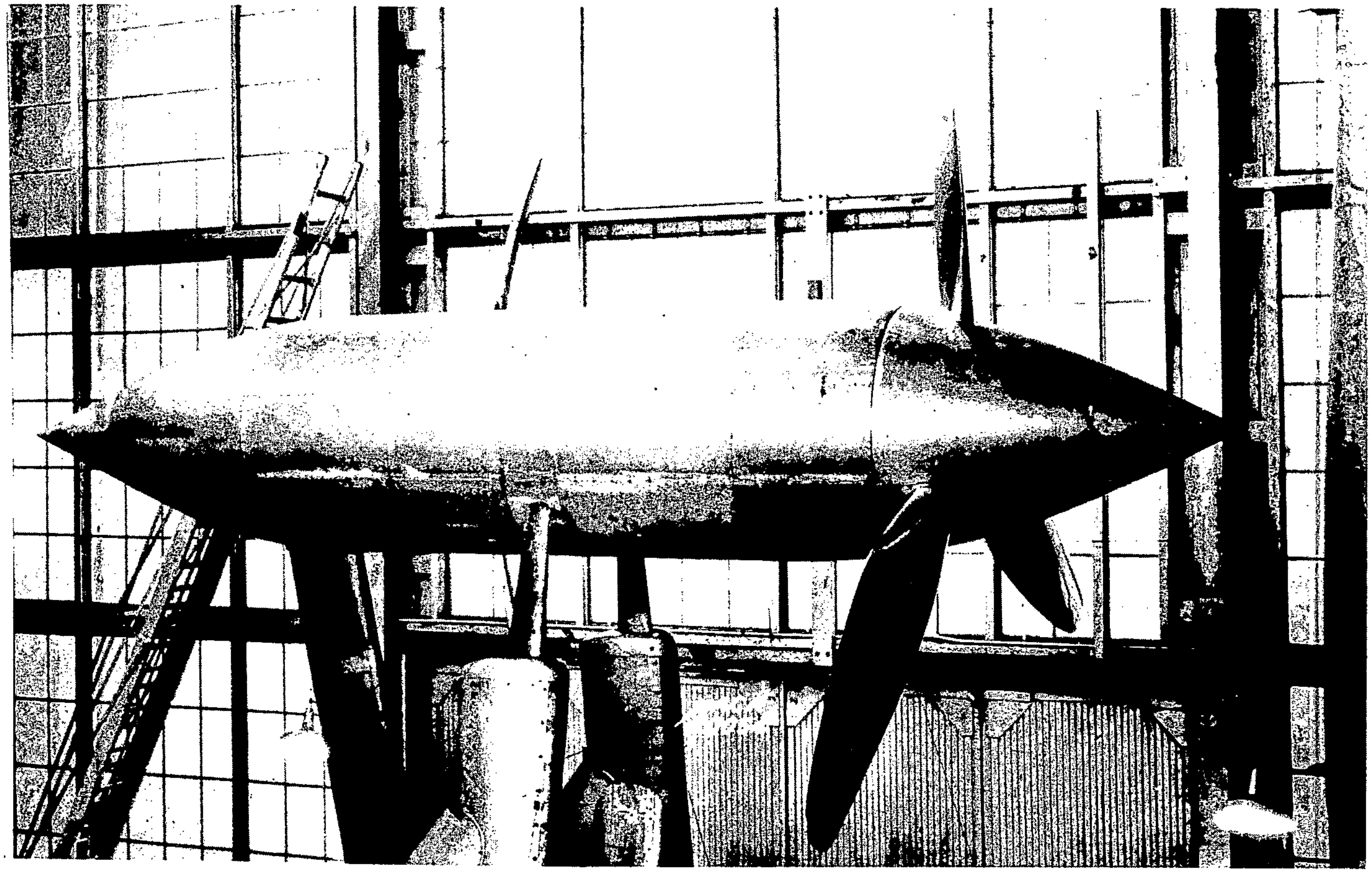
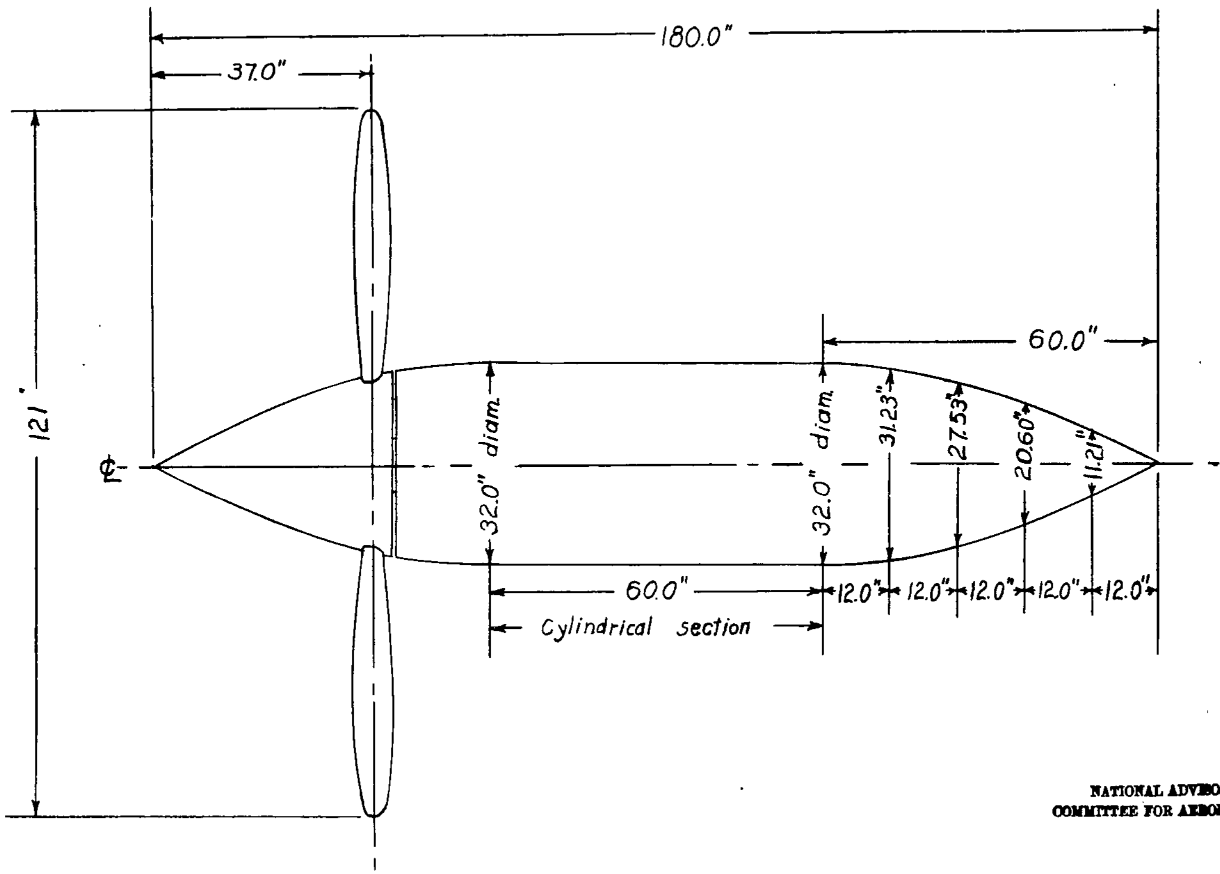


Figure 4.- Photograph of test set-up.



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Note: Front and rear nacelle lines are identical.

FIGURE 5 — Plan view showing dimensional details of nacelle.

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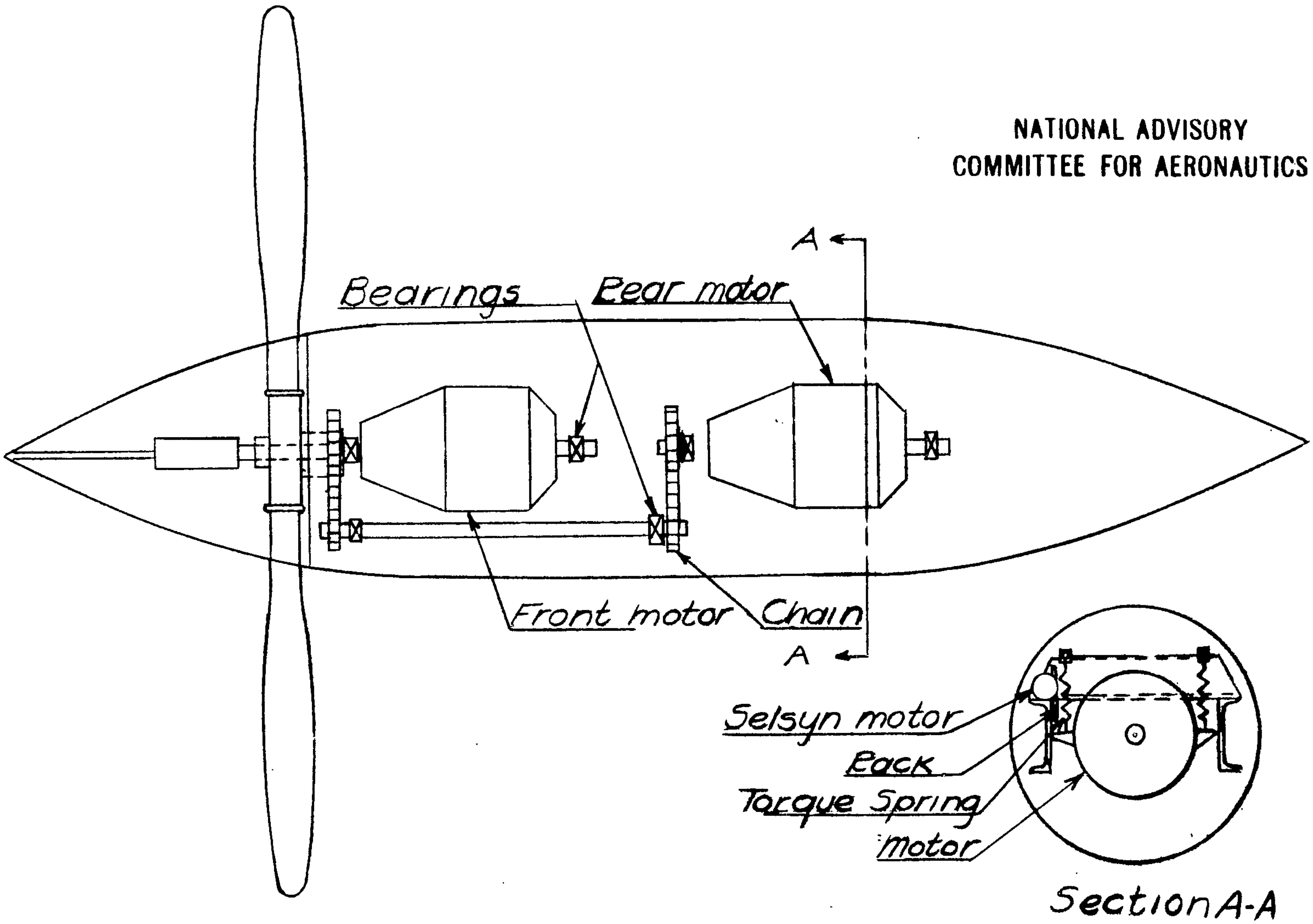

Figure 6.- propeller drive mechism.

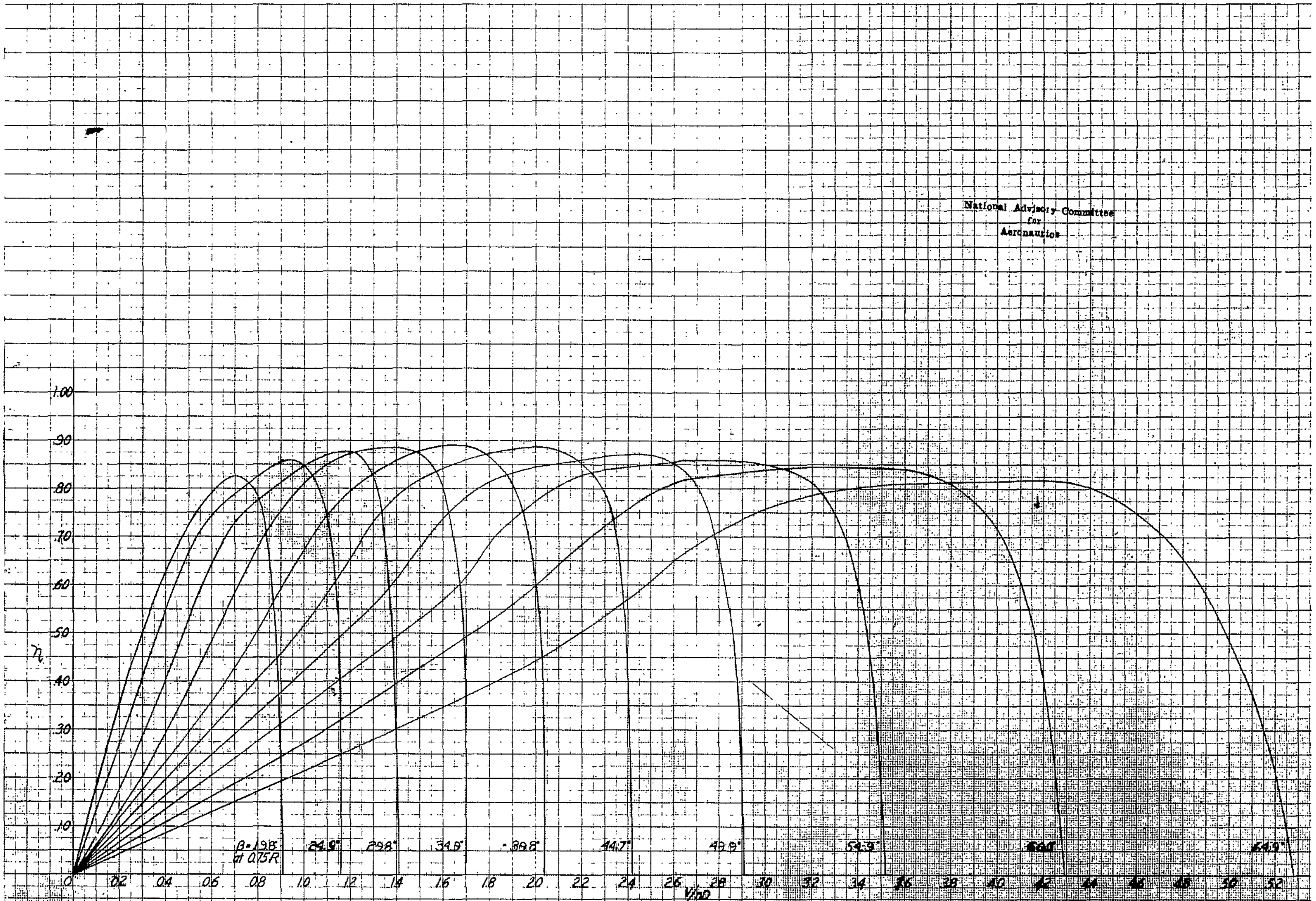

Figure 7.- Efficiency curves for propeller 6259 A-18, NACA 16 blade section throughout

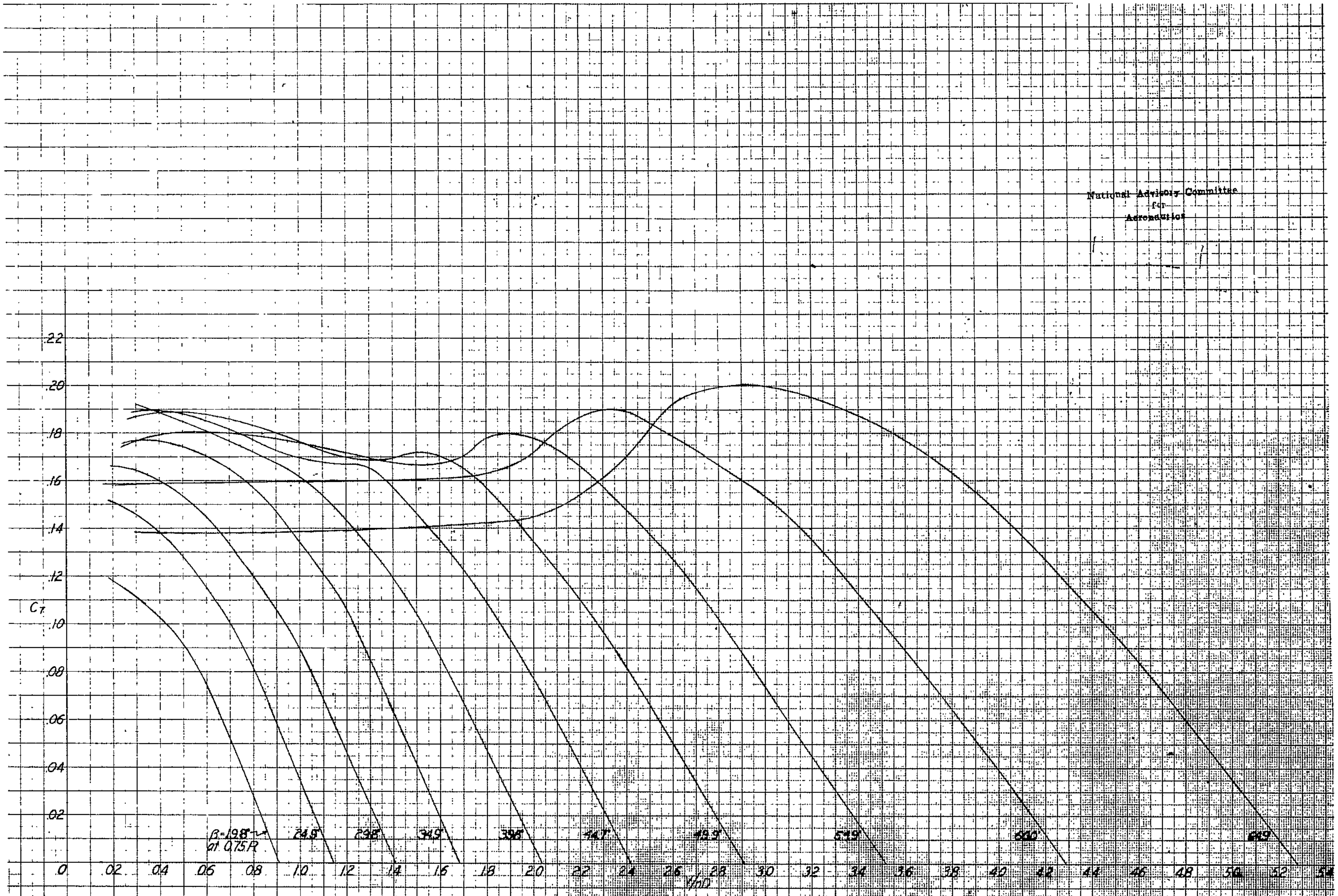

Figure 8.- Thrust-coefficient curves for propeller 6259A-18, NACA 16 blade section throughout

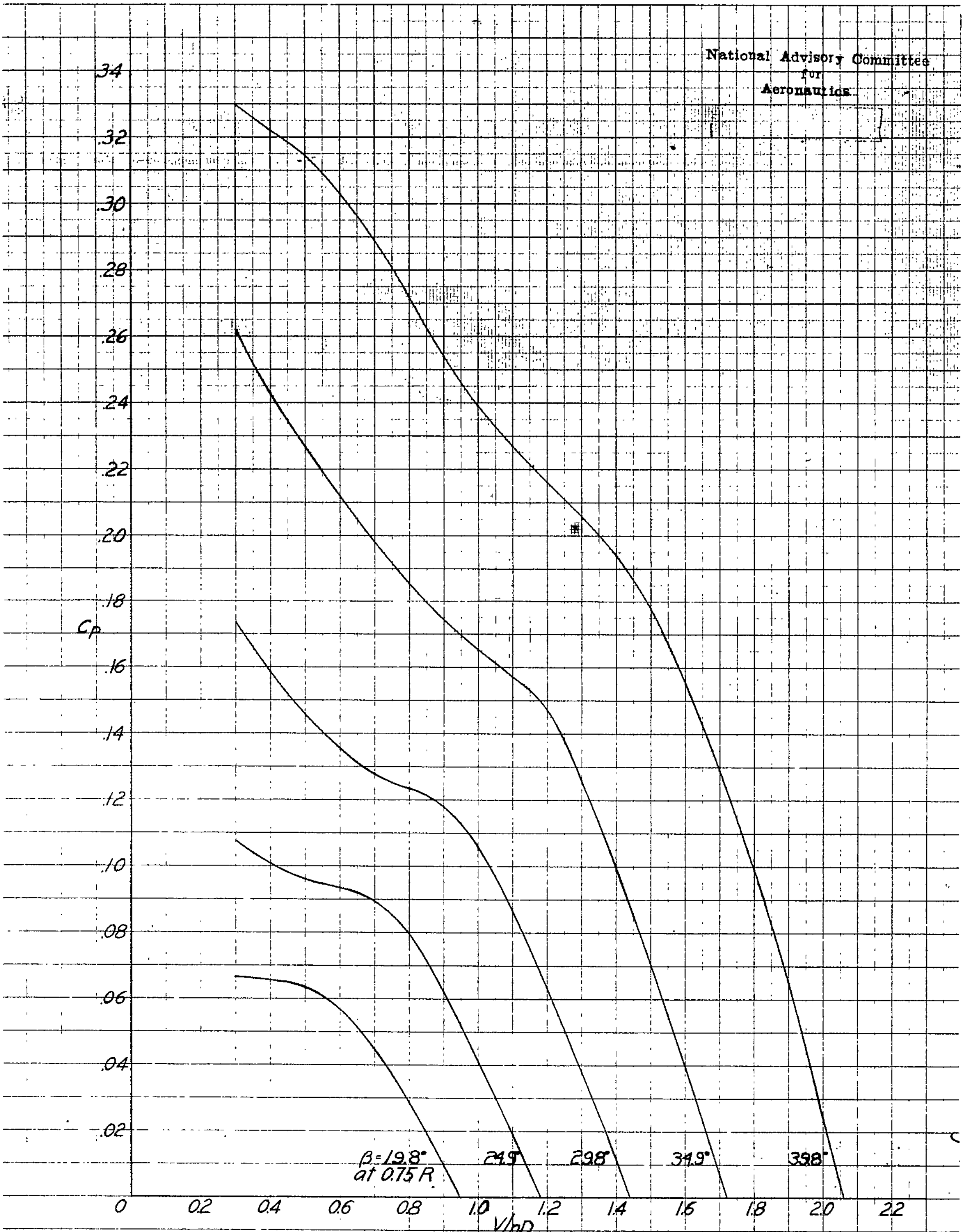

Figure 9a-Power-Coefficient curves for propeller 6259 A-18, NACA 16 blade section throughout

Fig. 9b

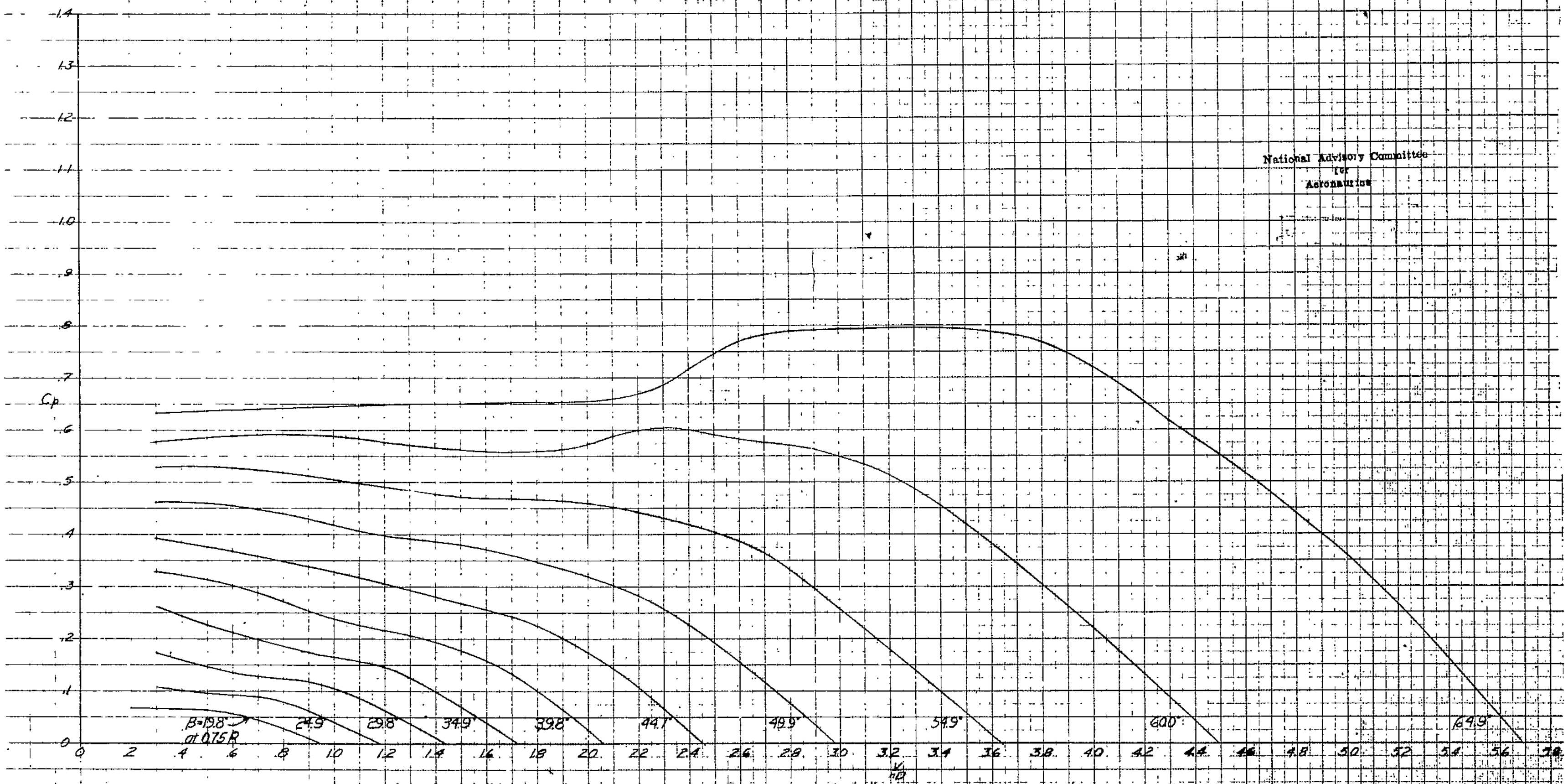

Figure 9b. Power-coefficient curves for propeller 6259A-18, NACA 16 blade section throughout

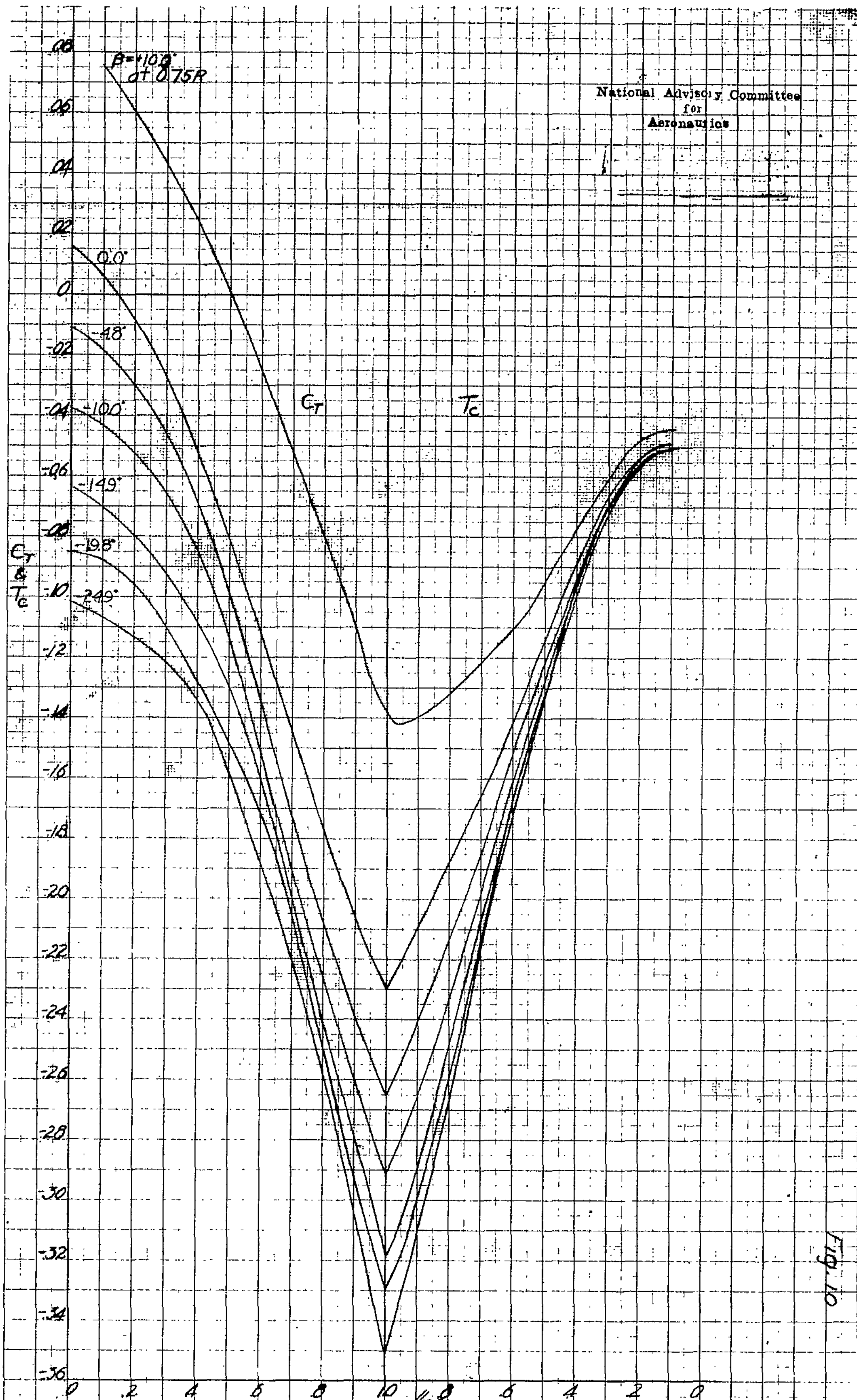

Figure 10.-Thrust-coefficient curves for propeller 6259 A-18, NACA blade section 7 throughout

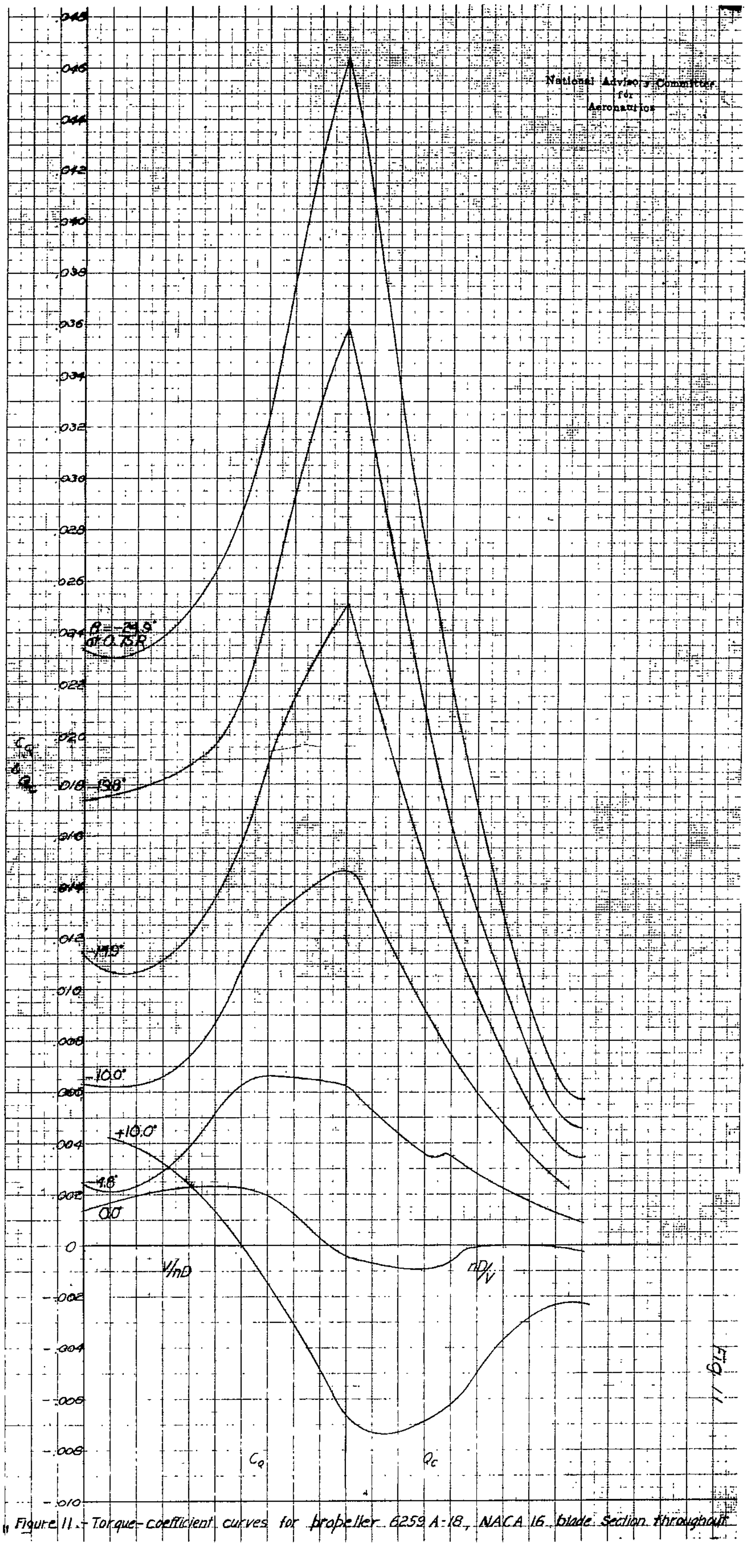

Figure 11.- Torque-coefficient curves for propeller 6259 A-18, NACA 16 blade section throughout.

Fig. 11

Fig. 12

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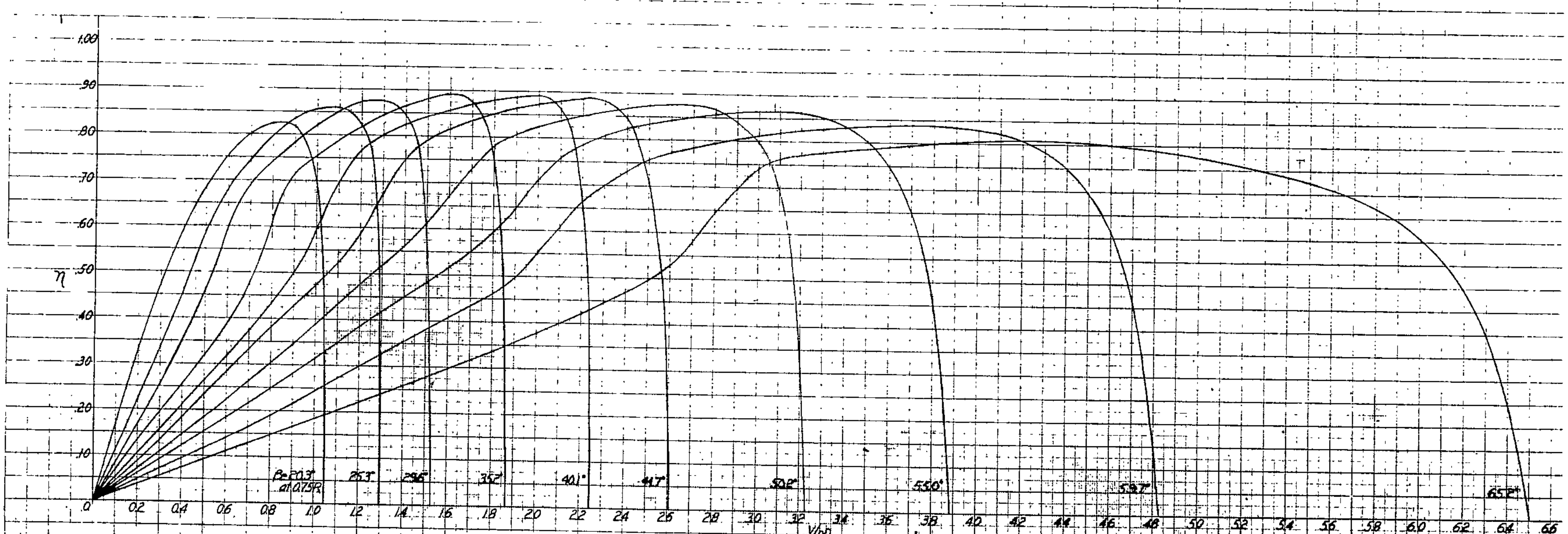

Figure 12.- Efficiency curves for propeller 6267 A-18, Clark Y blade section throughout

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Fig. 13

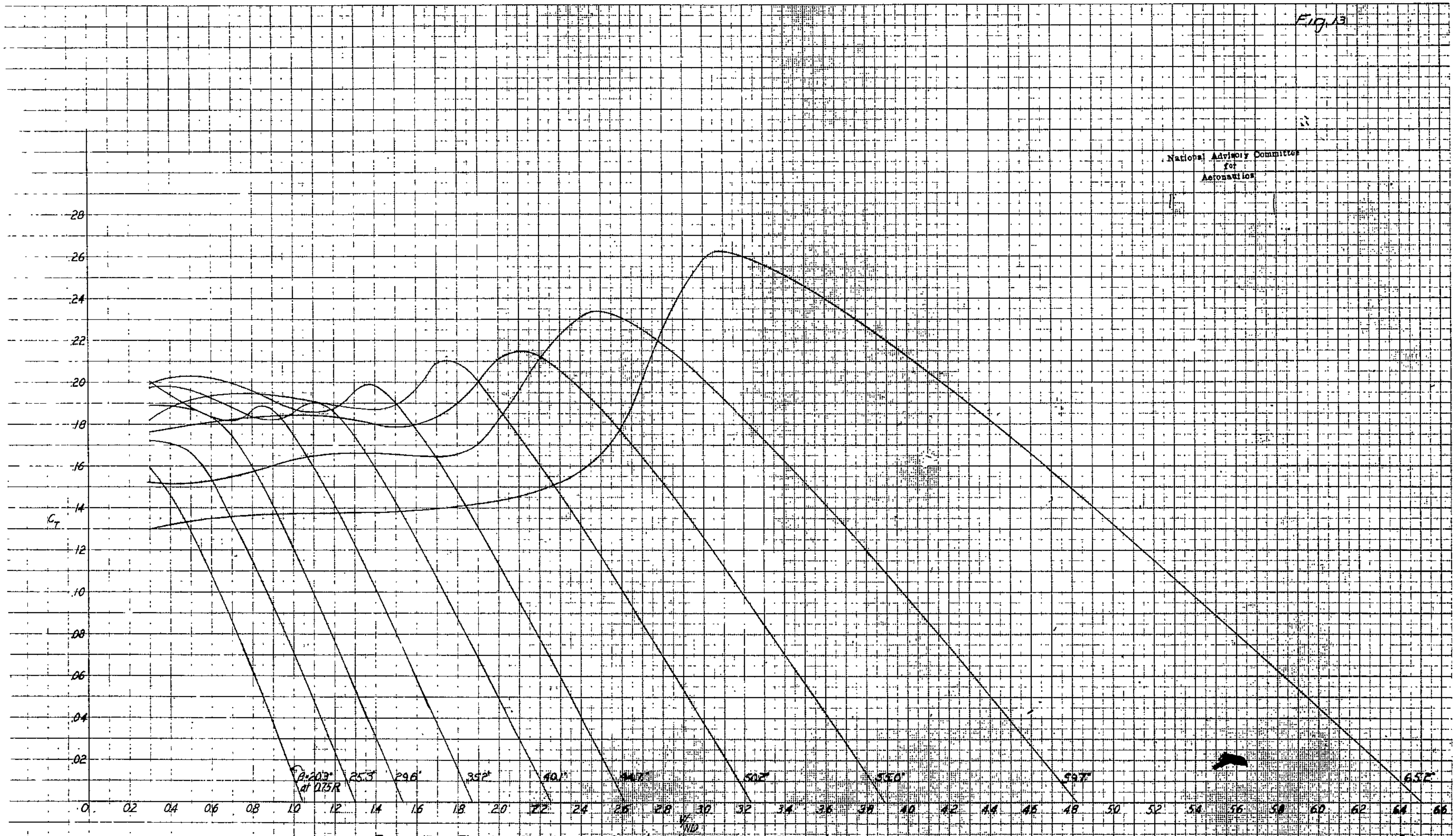

Figure 13.- Thrust-coefficient curves for propeller 5267A-18 Clark Y blade section throughout.

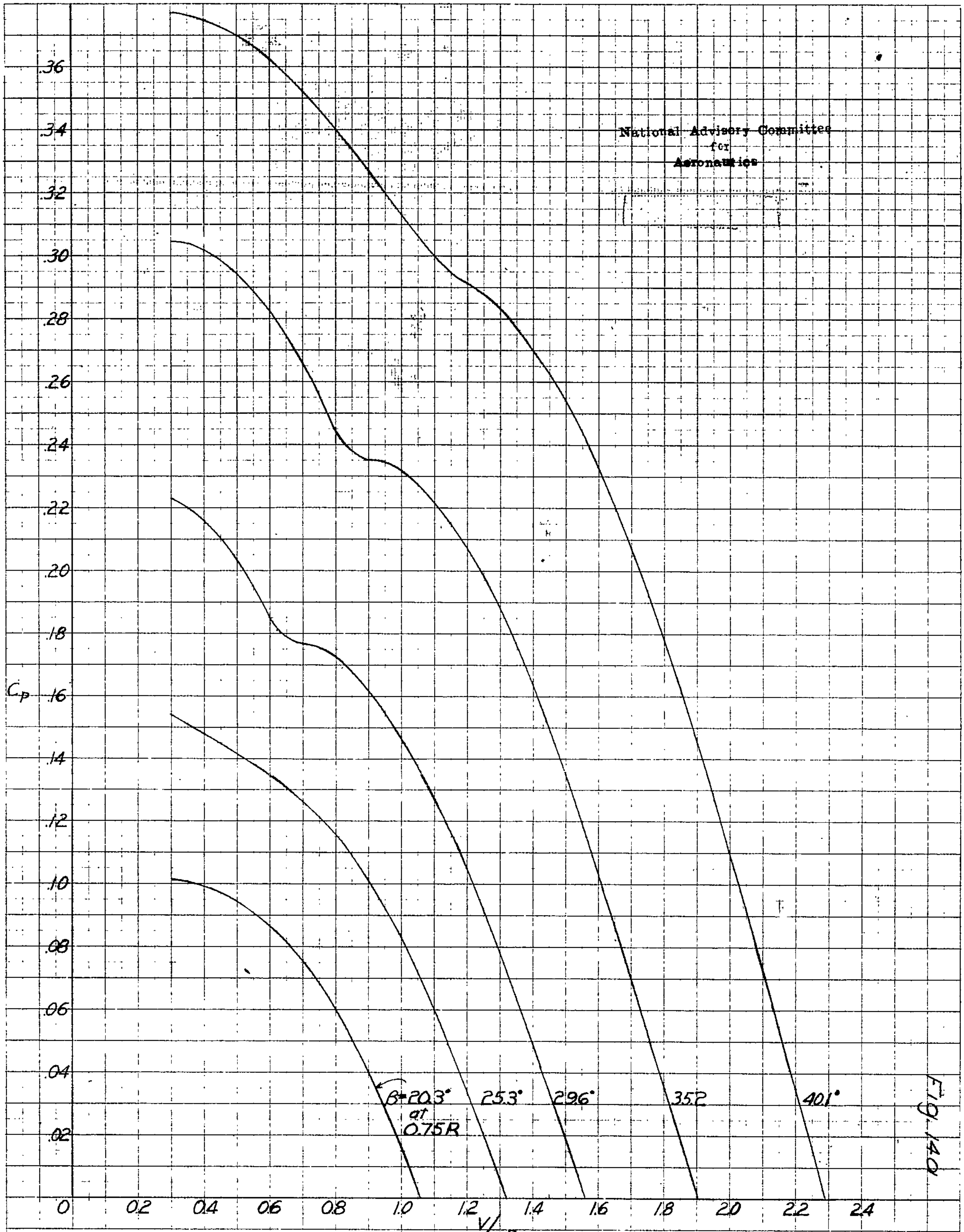

Figure 14a-Power-coefficient curves for propeller 6267A-18, Clark Y blade section throughout

Fig. 14b

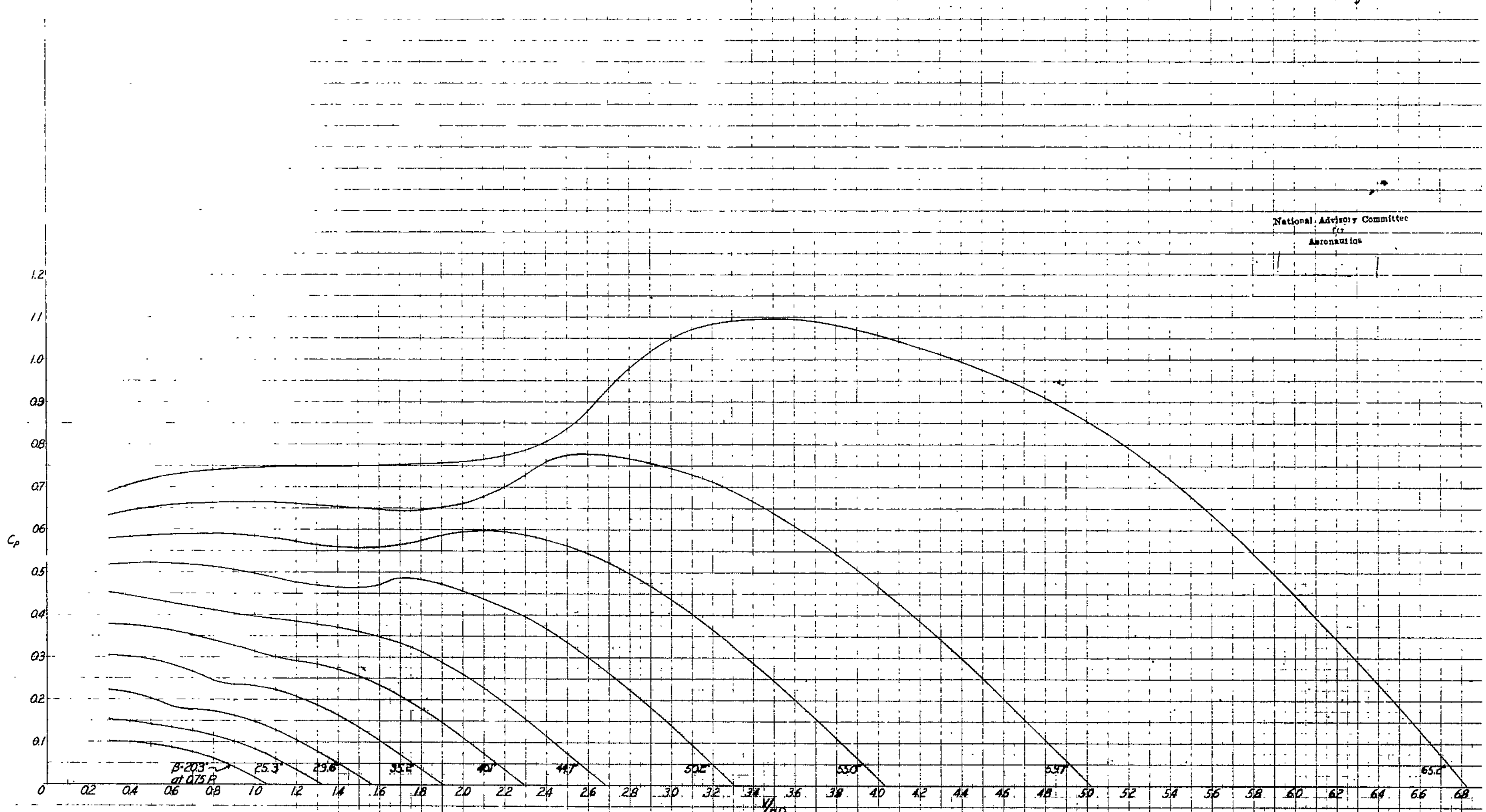

Figure 14 b. - Power-coefficient curves for propeller 6267 A-18, Clark Y blade section throughout

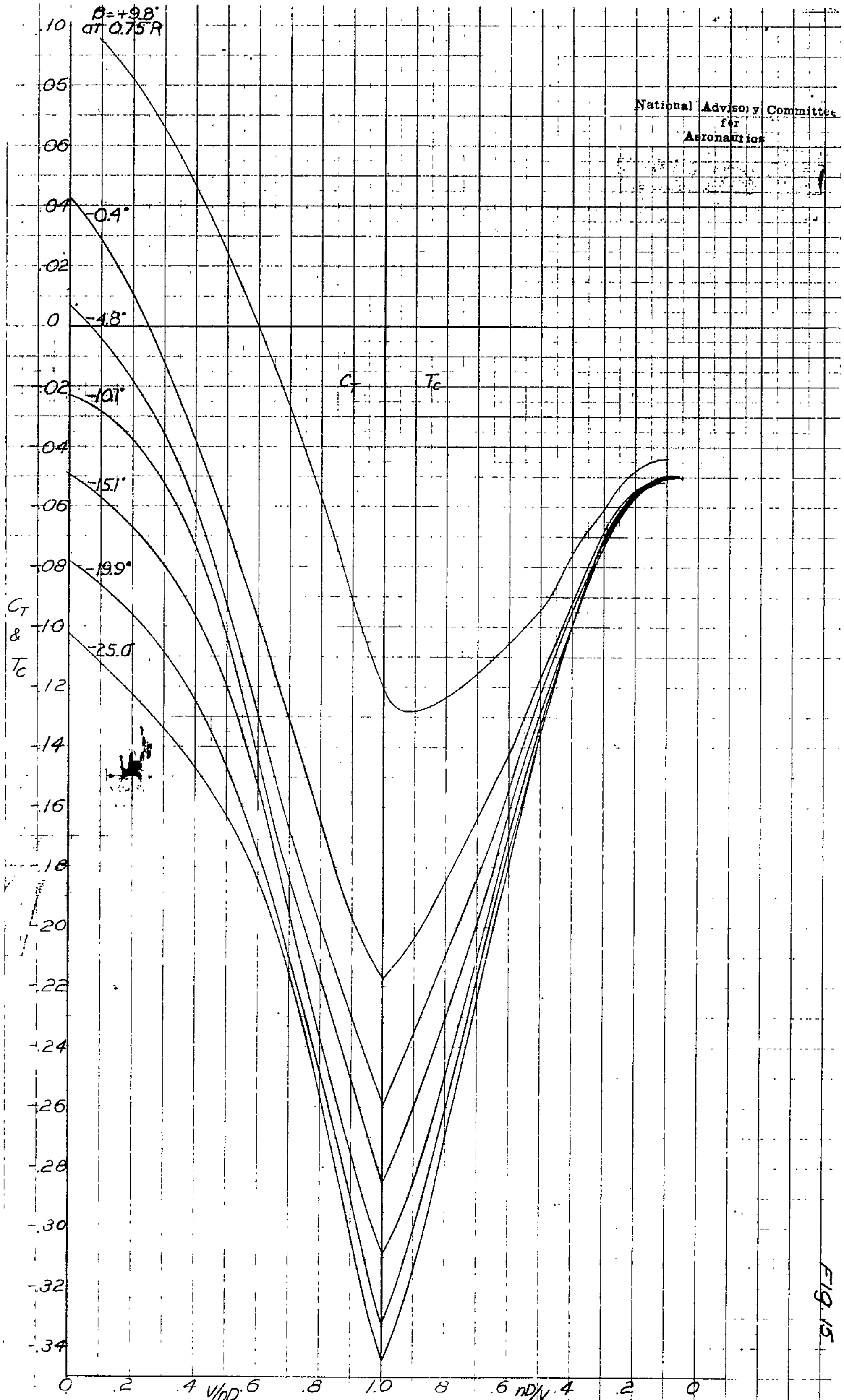

Figure 15.-Thrust-coefficient curves for propeller 6267 A-18, Clark Y blade section throughout

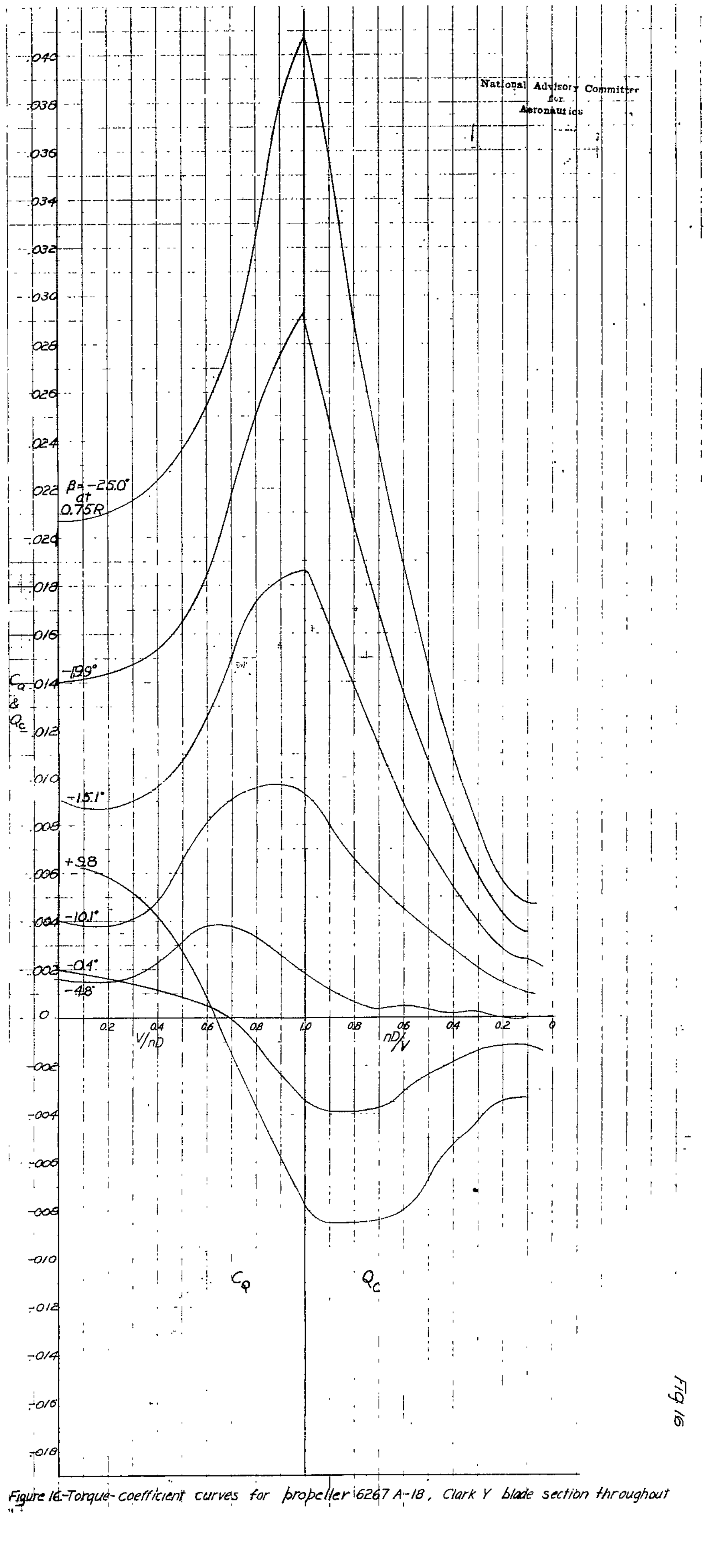

Figure 16-Torque-coefficient curves for propeller 6267 A-18, Clark Y blade section throughout

Fig 16

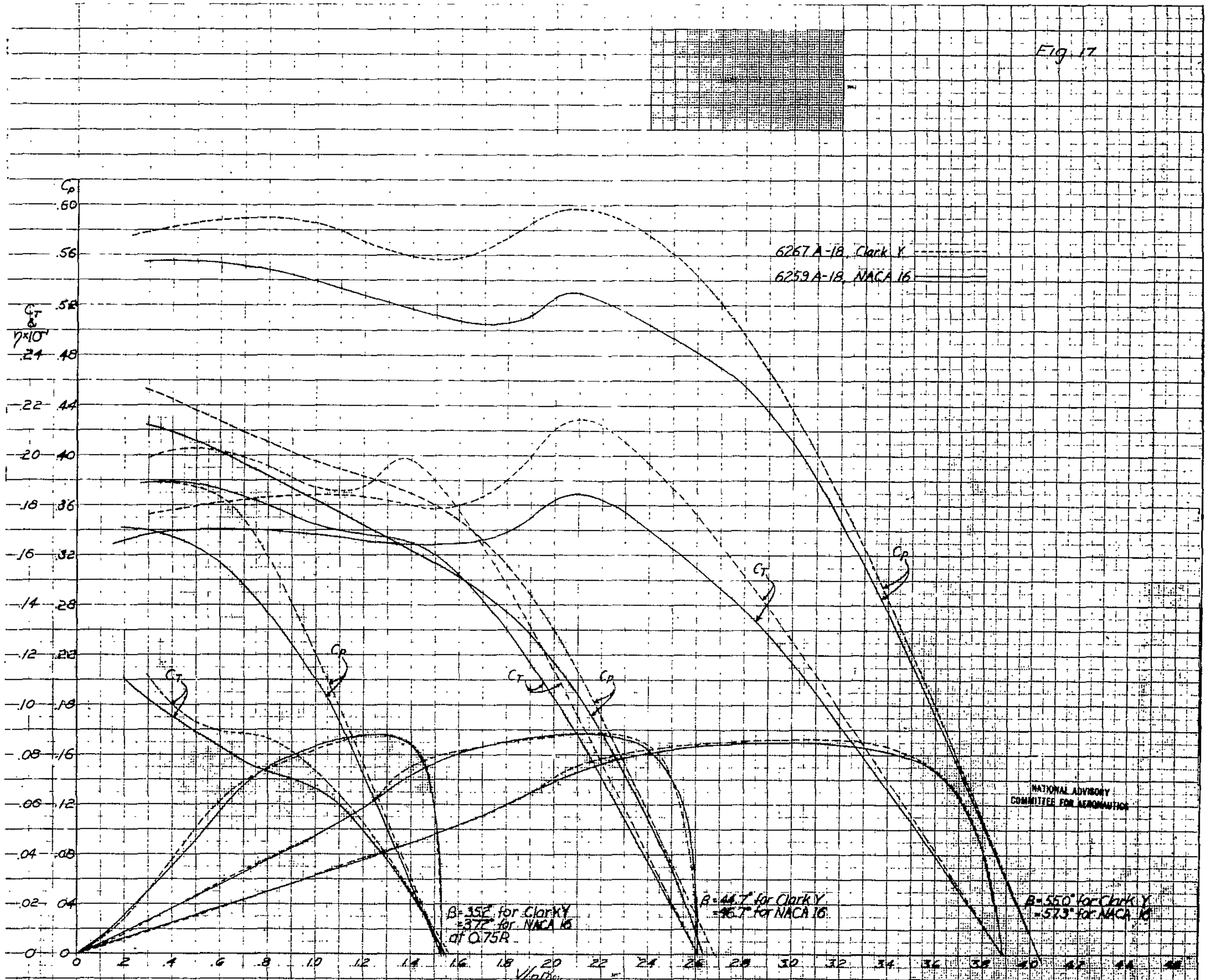

FIGURE 17- Comparison of propeller characteristic curves for propellers 6267 A-18, Clark Y, and 6259 A-18, NACA 16

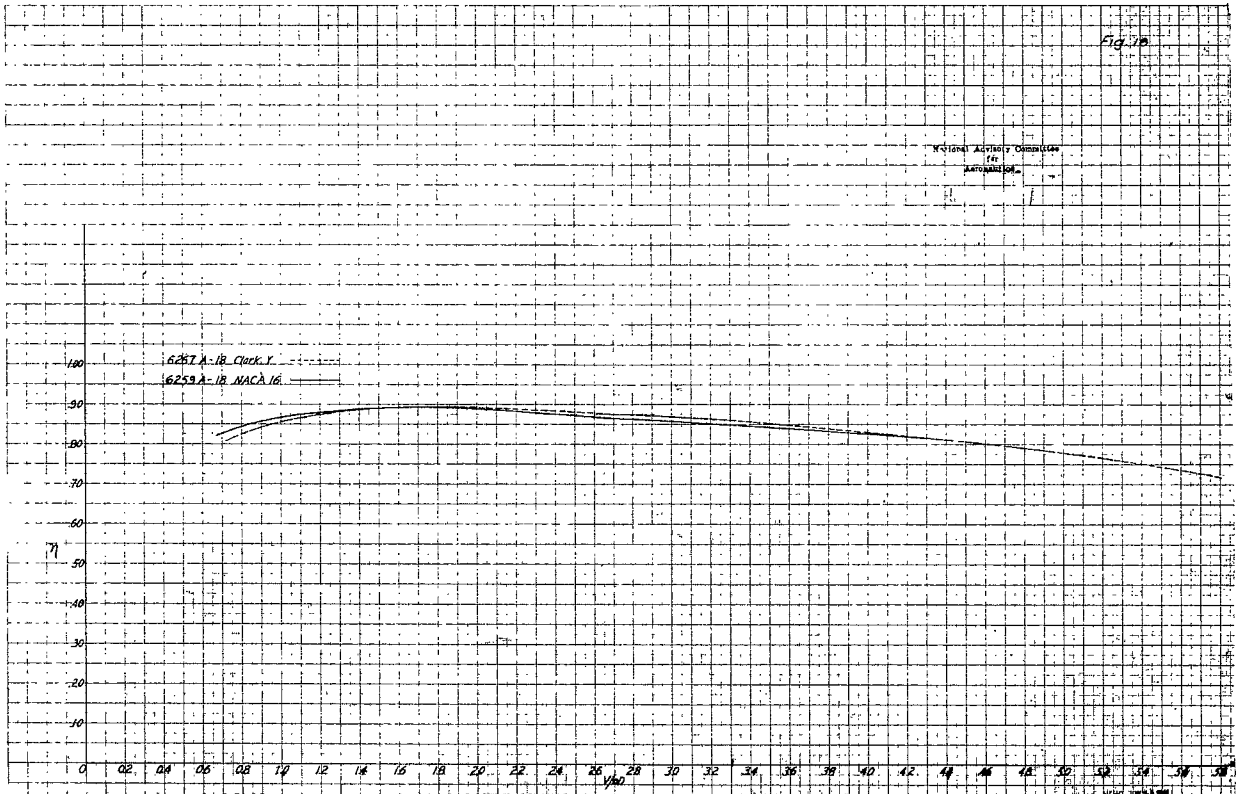

Figure 18. – Comparison of Efficiency Envelope Curves for Propellers 6267 A-18, Clark Y, and 6259 A-18, NACA 16

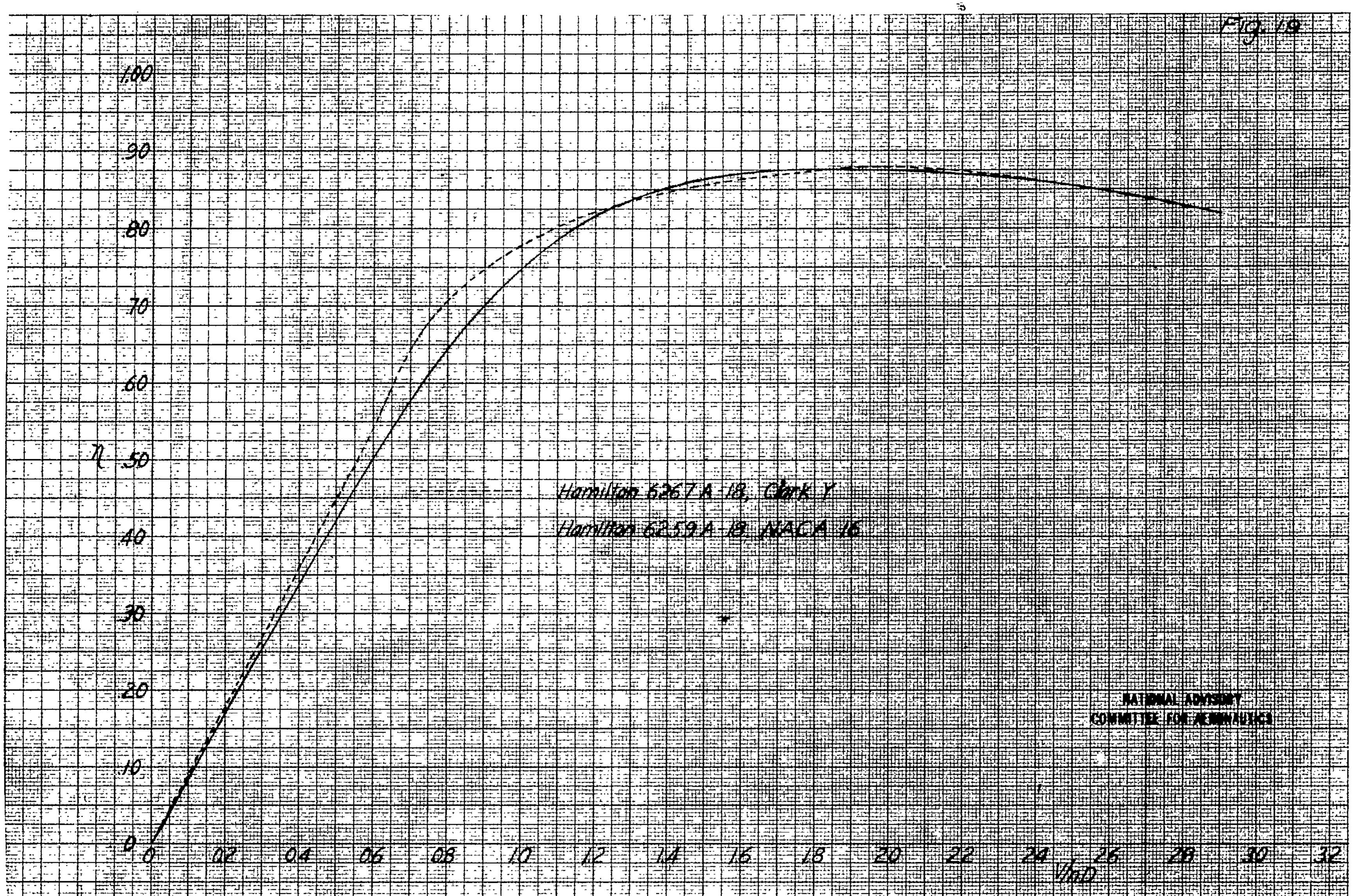

Figure 19-Efficiency comparison for propellers 6267A-18 and 6259A-18 at constant power $C_p=0.2$

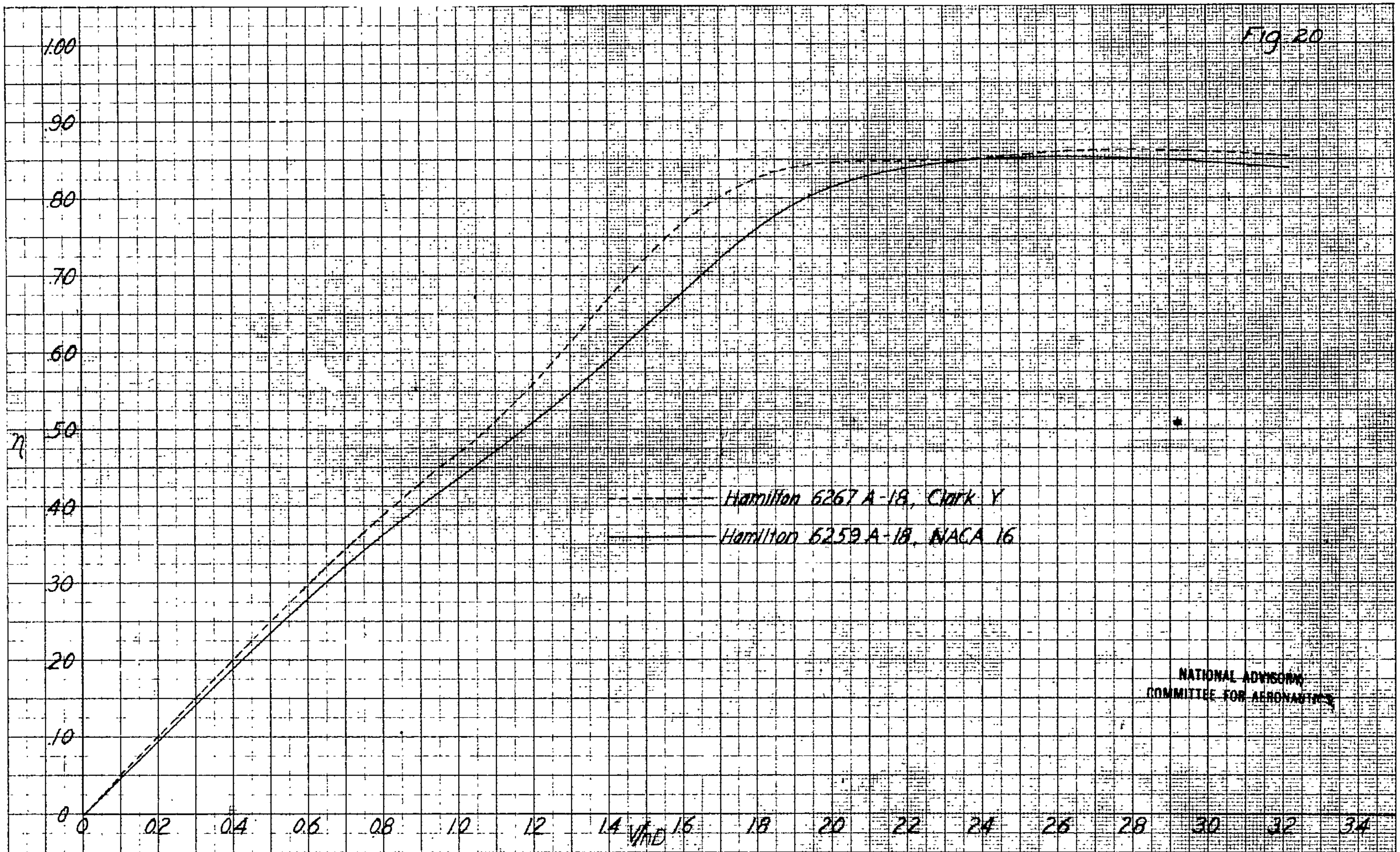

Figure 20.- Efficiency Comparison for propellers 6267 A-18 and 6259 A-18 at constant power - C_p=0.4

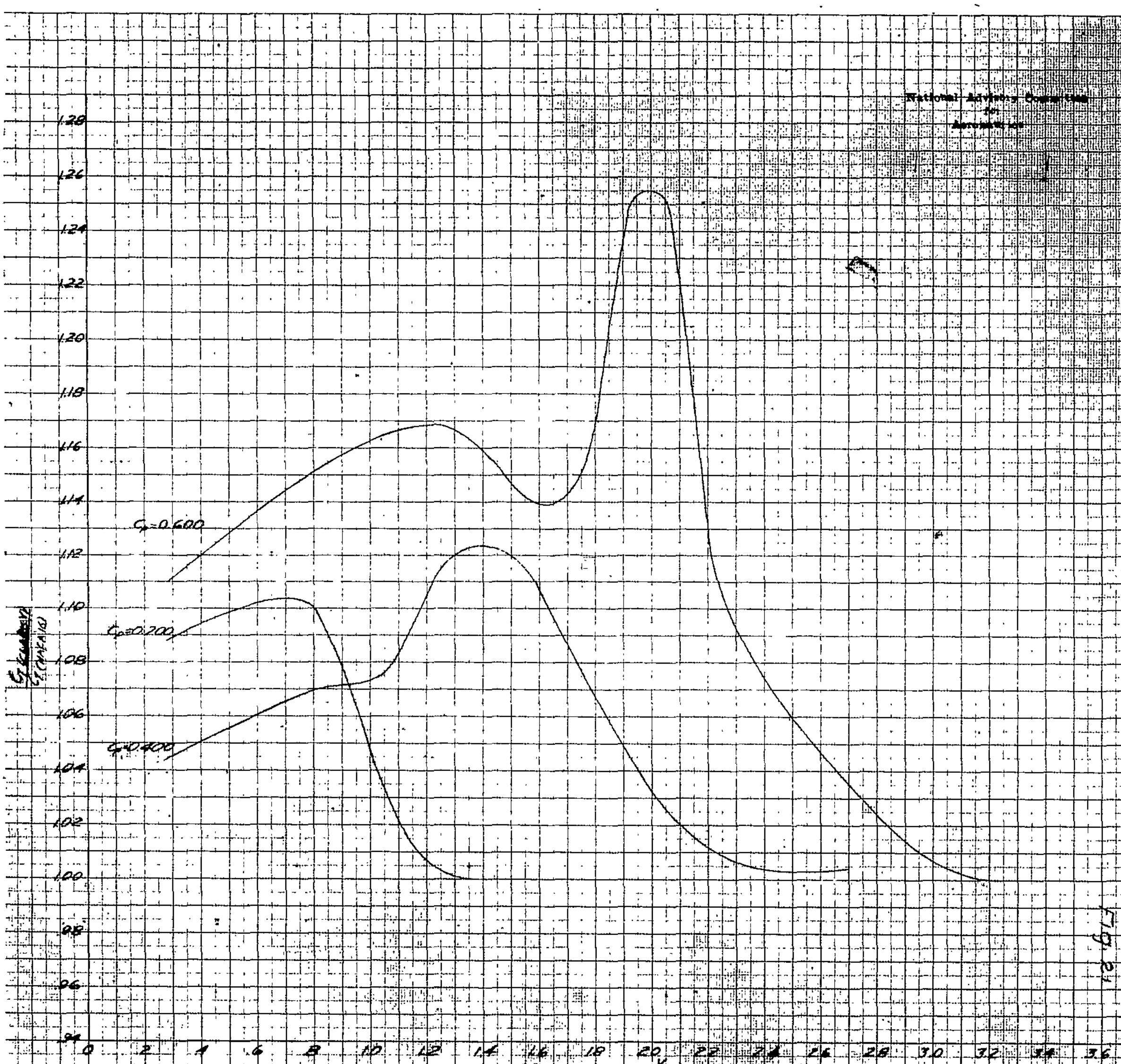

FIGURE 21 Thrust-ratio comparisons C_T clarkY/C_T (NACA 16)